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(54) Plasma reactors for processing semiconductor wafers

Plasmareaktoren für die Bearbeitung von Halbleiterscheiben

Réacteurs à plasma pour le traitement de tranches semi-conductrices

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Description

[0001] The invention is related to plasma reactors for processing semiconductor wafers, and in particular confinement of the processing plasma in the reactor within a limited processing zone.

[0002] Plasma reactors, particularly radio frequency (RF) plasma reactors of the type employed in semiconductor wafer plasma processing in the manufacturing of microelectronic integrated circuits, confine a plasma over a semiconductor wafer in the processing chamber by walls defining a processing chamber. Such an approach for plasma confinement has several inherent problems where employed in plasma reactors for processing semiconductor wafers.

[0003] First, the walls confining the plasma are subject to attack from ions in the plasma, typically, for example, by ion bombardment. Such attack can consume the material in the walls or introduce incompatible material from the chamber walls into the plasma process carried out on the wafer, thereby contaminating the process. Such incompatible material may be either the material of the chamber wall itself or may be material (e.g., polymer) previously deposited on the chamber walls during plasma processing, which can flake off or be sputtered off. As one example, if the chamber walls are aluminum and the plasma process to be performed is plasma etching of silicon dioxide, then the material of the chamber wall itself, if sputtered into the plasma, is incompatible with the process and can destroy the integrity of the process.

[0004] Second, it is necessary to provide certain openings in the chamber walls and, unfortunately, plasma tends to leak or flow from the chamber through these openings. Such leakage can reduce plasma density near the openings, thereby upsetting the plasma process carried out on the wafer. Also, such leakage can permit the plasma to attack surfaces outside of the chamber interior. As one example of an opening through which plasma can leak from the chamber, a wafer slit valve is conventionally provided in the chamber side wall for inserting the wafer into the chamber and withdrawing the wafer from the chamber. The slit valve must be unobstructed to permit efficient wafer ingress and egress. As another example, a pumping annulus is typically provided, the pumping annulus being an annular volume below the wafer pedestal coupled to a vacuum pump for maintaining a desired chamber pressure. The chamber is coupled to the pumping annulus through a gap between the wafer pedestal periphery and the chamber side wall. The flow of plasma into the pumping annulus permits the plasma to attack the interior surfaces or walls of the pumping annulus. This flow must be unobstructed in order for the vacuum pump to efficiently control the chamber pressure, and therefore the pedestal-to-side wall gap must be free of obstructions.

[0005] EP-A-0651425 discloses a plasma reactor including a vacuum chamber into which a precursor etchant species such as C_2F_6 gas is introduced through a gas inlet which is excited into a plasma state by RF energy from an RF antenna. The chamber is bounded on its sides by a cylindrical quartz wall. A semiconductor wafer having a thin film structure thereon to be etched is firmly held on the top of a pedestal by a electrostatic chuck in the chamber. The chuck consists of polyimide sheets which insulate a copper film conductor. To reduce the rate at which the plasma etches the polyimide insulation and the wafer backside, a magnet is placed in a ring inside the quartz side wall around a circumferential gap between the wafer periphery and the side wall. However, in this arrangement, an open magnetic circuit is created. Such an open magnetic circuit may interfere with plasma characteristics at the processing surface, as well as introduce adverse electrical effects to the surface structures of the wafer.

[0006] Japanese Patent Application No. 7-22389 discloses a microwave plasma processing device including a vacuum chamber including a plasma generation device, a stage in the chamber on which a semi-conductor substrate may be mounted having a source of RF power coupled to the stage. There is a gap between the periphery of the stage and the wall of the chamber and below the stage a vacuum pump for reducing pressure in the chamber. A plasma confinement system is provided comprising annular permanent magnets on the stage and encircling the chamber wall adjacent the stage to create a magnetic field across the gap between the stage and chamber wall to prevent plasma from flowing down between the stage and chamber wall. The annular magnets create an open magnetic circuit which, for the reasons indicated above, may interfere with plasma characteristics at the processing surface as well as introduce adverse electrical facts to the surface structures of the wafer.

[0007] US-A-4721891 discloses that a plasma flow through an elongate gap can be quenched by a straight magnetic field across the gap, the field being generated by poles of opposite plurality facing each other across the gap.

[0008] It is an object of the invention to devise a magnetic plasma confinement system within a chamber which does not interfere with the plasma characteristics at the processing surface.

[0009] This invention provides an RF plasma reactor for processing a semiconductor wafer, comprising:

a reactor chamber bounded by a chamber wall, and a gas inlet;

an RF power source and an RF power coupler proximal said chamber and connected to said RF power source;

a wafer pedestal in said chamber for supporting a semiconductor wafer to be processed in said reactor, said wafer pedestal dividing said chamber into

an upper processing portion and a lower portion separated by an annular gap between said wafer pedestal and said chamber wall for gas flow between said upper and lower portions of said chamber;

and annular magnetic means extending around the gap to prevent flow of plasma ions through the gap to the lower portion of the chamber; said magnetic means having annular magnetic poles of opposite magnetic polarity placed in face to face relation on opposing sides of said gap and having sufficient magnetic strength to confine plasma ions in said upper processing portion;

wherein that the annular magnetic means are of horseshoe form providing said pair of annular poles of opposite polarity in face to face relation across said gap and extending below the gap to provide a closed magnetic circuit without lines of flux extending into the chamber.

[0010] In one arrangement according to the invention the annular magnetic means may comprise a pair of horseshoe shaped annular magnets providing two pairs of oppositely facing annular poles of opposing polarities, one of said pairs being disposed across the gap and the other pair of poles being disposed below the gap, the lines of magnetic flux extending straight between said pairs of poles to complete the magnetic circuit provided by said magnetic means.

[0011] In a preferred arrangement the other of said pair of annular poles is located below the lower portion of the chamber.

[0012] More specifically, a first one of said pairs of magnets may comprise an inner cylindrical core concentric with said wafer pedestal and having an inner top end and an inner bottom end, and a pair of inner annuli extending radially outwardly from said inner top end and said inner bottom end respectively, the poles of said first magnet being comprised in said pair of inner annuli respectively; the other one of said pair of magnets may comprise an outer cylindrical core concentric with and surrounding said inner cylindrical core and having an outer top and an outer bottom end and a pair of outer annuli extending radially inwardly from said outer top end and said outer bottom end respectively, the poles of said other magnet being comprised within said pair of outer annuli respectively.

[0013] In an alternative arrangement the annular magnetic means may comprise a single horseshoe shaped ring magnet having an annular core and said pair of annular poles of opposite polarities are located in face to face on opposite sides of the annular gap and said core extends through said lower portion of said chamber.

[0014] In the latter construction gas passages may extend through said core for permitting gas flow through said lower portion of said chamber.

[0015] In addition, a protective coating may be provided around said core portion.

[0016] More specifically, the annular core may comprise an inner cylindrical core and a concentric outer cylindrical core, the upper ends of the inner and outer cores having respectively outward and inwardly facing annular poles of opposing polarities facing across the gap and the lower ends of the inner and outer cores being connected by a radially extending core extending through the lower portion of the chamber.

[0017] The invention may also include a slit valve opening forming a gap in said chamber wall having opposing sides and a pair of valve magnets disposed side-by-side whereby each pole of each valve magnet faces an opposite pole of the other valve magnet, each of said valve magnets having poles of opposite polarity located along respective opposing sides of said slit valve.

[0018] For example said first pair of facing pole of the two valve magnets may face each other across said slit valve opening while the second pair of facing poles of said two valve magnets may face each other at a location radially outwardly displaced of the chamber wall from said slit valve opening. Said pairs of facing poles may be separated by gaps sufficient to permit a passage of a semiconductor wafer therebetween. For example said valve magnets may be horseshoe magnetics.

[0019] The Invention further provides an RF plasma reactor for processing a semiconductor wafer comprising:

a reactor chamber bounded by a chamber wall, and a gas inlet;

an RF power'source and an RF power coupler proximal said chamber and connected to said RF power source;

a wafer pedestal in said chamber for supporting a semiconductor wafer to be processed in said reactor;

and a slit valve opening through said chamber wall affording ingress and egress of a wafer to and from said chamber, said slit valve opening having opposing sides defining said opening;

wherein that a pair of valve magnets is provided, each having a pole located along a respective opposing sides of said slit valve opening,

a first pair of poles of the respective valve magnets of opposite polarity being located along opposite sides of said slit valve opening facing each other and adjacent the opening while a second pair of poles of the respective valve magnets of opposite polarity facing each other at a location outwardly displaced away from said slit valve opening, said pair of valve magnets thereby constituting a closed magnet circuit.

[0020] By arranging the opposing magnetic poles as

part of a closed magnetic circuit, the magnetic poles are prevented from perturbing the plasma processing of the semiconductor wafer.

[0021] Moreover, the interior surface of the reactor pumping annulus is shielded from the plasma by preventing plasma from flowing through the gap between the wafer pedestal and the chamber side wall without obstructing free flow of charge-neutral gas through the gap.

[0022] The following is a description of an arrangement not in accordance with the present invention by way of background followed by some specific embodiments of the invention, reference being made to the accompanying drawings, in which:

FIG. 1 is a cut-away side view of a plasma reactor not in accordance with the invention employing open magnetic circuits.

FIG. 2 is an enlarged view of part of Figure 1 showing the magnetic confinement apparatus near the pedestal-to-side wall gap.

FIG. 3 is an enlarged view of part of Figure 1 showing the magnetic confinement apparatus near the wafer slit valve.

FIGS. 4A and 4B correspond to a side view of a plasma reactor in accordance with a preferred embodiment of the invention employing closed magnetic circuits having pairs of opposed magnets.

FIG. 5 is a perspective view of a pair of opposing ring magnets juxtaposed across the pedestal-to-side wall gap.

FIG. 6 is a perspective view of a pair of opposing magnets juxtaposed across the wafer slit valve.

FIG. 7 is a cut-away side view of a plasma reactor in which the closed magnetic circuit is a single magnet whose opposing poles are juxtaposed across the pedestal-to-side wall gap and which are joined by a core extending across the pumping annulus.

FIG. 8 is a top view of the single magnet of FIG. 7 and showing gas flow holes through the core joining the opposite poles of the magnet.

Conventional Reactor Elements:

[0023] An RF plasma reactor shown in Figures 1 to 3 which is not in accordance with the present invention will be described first by way of background. The reactor for processing a semiconductor wafer has a vacuum chamber 10 enclosed by a cylindrical side wall 12, a ceiling 14 and a floor 16. A wafer pedestal 18 supports a semiconductor wafer 20 which is to be processed. A plasma precursor gas is injected into the chamber 10 through a gas injector 22 from a gas supply 24. Plasma source power is coupled into the chamber 10 in any one of several ways. For example, the reactor may be a "diode" configuration, in which case RF power is applied across a ceiling electrode 26 and the wafer pedestal 18. This is accomplished by connecting the pedestal 18 and the ceiling electrode 26 to either one of two RF power sources 28,30. Alternatively, a cylindrical side coil 32 wound around the chamber side wall 12 is connected to an RF power source 34. Alternatively to the foregoing, or in addition therefor, a top coil 36 is connected to an RF power supply. As is convention, the wafer pedestal 18 may have its own independently controllable RF power supply 28 so that ion bombardment energy at the wafer surface can be controlled independently of plasma density, determined by the Rf power applied to the coil 32 or the coil 36.

[0024] A vacuum pump 40 is coupled to the chamber 10 through a passage 42 in the floor 16. The annular space between the periphery of the wafer pedestal 18 and the floor 16 forms a pumping annulus 44 through which the vacuum pump 40 evacuates gas from the chamber 10 to maintain a desired processing pressure in the chamber 10. The pumping annulus 44 is coupled to the interior of the chamber 10 through an annular gap 46 between the periphery of the wafer pedestal 18 and the chamber side wall 14. In order for pump 40 to perform efficiently, the gap 46 is preferably free of obstructions.

[0025] A conventional slit valve opening 50 of the type well-known in the art having a long thin opening in the chamber side wall 14 provides ingress and egress for a semiconductor wafer 52 to be placed upon and withdrawn from the wafer pedestal 18.

[0026] The walls 12, 14 confining the plasma within the chamber 10 are subject to attack from plasma ions and charged radicals, typically, for example, by ion bombardment. Such attack can consume the material in the walls 12, 14 or introduce incompatible material from the chamber walls 12, 14 into the plasma process carried out on the wafer 52, thereby contaminating the process. Such incompatible material may be either the material of the chamber wall itself or may be material (e.g., polymer) previously deposited on the chamber walls during plasma processing, which can flake off or be sputtered off. Plasma reaching the chamber walls can cause polymer deposition thereon.

[0027] The openings from the interior portion of the chamber 10, including the pedestal-to-side wall gap 46 and the slit valve opening 50, permit the plasma to leak or flow from the chamber 10. Such leakage can reduce plasma density near the openings 46, 50, thereby upsetting the plasma process carried out on the wafer 52. Also, such leakage can permit the plasma to attack surfaces outside of the chamber interior. The flow of plasma into the pumping annulus 44 through the gap 46 permits the plasma to attack the interior surfaces or walls of the

pumping annulus 44. Thus, the designer must typically take into account not only the materials forming the chamber ceiling 12 and side wall 14, but in addition must also take into account the materials forming the pumping annulus, including the lower portion 56 of the side wall 12, the floor 16 and the bottom peripheral surface 58 of the wafer pedestal 18, which complicates the design. Such a loss of plasma from the chamber 10 also reduces plasma density or requires more plasma source power to maintain a desired plasma density over the wafer 52.

Magnetic Confinement:

[0028] In order to prevent plasma from flowing from the chamber 10 into the pumping annulus, a magnetic field perpendicular to the plane of the gap 46 and perpendicular to the direction of gas flow through the gap 46 is provided across the gap 46. This is accomplished by providing an opposing pair of magnetic poles 60, 62 juxtaposed in facing relationship across the gap 46. In the example according to FIG. 2, the magnetic pole 60 is the north pole of a magnet 64 located at the periphery of the wafer pedestal 18 while the magnetic pole 62 is the south pole of a magnet 66 next to the inner surface of the side wall 12. The example of FIG. 2 may be regarded as an open magnetic circuit because the returning magnetic field lines of flux 68 in FIG. 2 radiate outwardly as shown in the drawing.

[0029] In order to prevent plasma from flowing from the chamber 10 through the slit valve opening 50, a magnetic field perpendicular to the plane of the slit valve opening 50 and perpendicular to the direction of gas flow through the slit valve opening 50 is provided across the slit valve opening 50. This is preferably accomplished by providing an opposing pair of magnetic poles 70, 72 juxtaposed in facing relationship across the slit valve opening 50. In the example according to FIG. 3, the magnetic pole 70 is the north pole of a magnet 74 extending across the bottom edge of the slit valve opening 50 while the magnetic pole 72 is the south pole of a magnet 76 extending along the top edge of the slit valve opening 50. The example of FIG. 3 may also be regarded as an open magnetic circuit because the returning magnetic field lines of flux 78 in FIG. 3 radiate outwardly as shown in the drawing.

Embodiments of the present invention

[0030] One potential problem with the returning lines of magnetic flux 68 (FIG. 2) and 78 (FIG. 3) is that some returning flux lines extend near the wafer 52 and may therefore distort or perturb plasma processing of the wafer 52. In order to minimize or eliminate such a problem in accordance with the present invention a closed magnetic circuit (one in which returning magnetic lines of flux do not extend into the chamber) is employed to provide the opposing magnetic pole pairs 60, 62 and 70, 72. For example, in the embodiment of FIGS. 4 and 5, the opposing magnetic poles 60, 62 across the gap 44 are each a pole of a respective horseshoe ring magnet 80, 82 concentric with the wafer pedestal 18. The horseshoe ring magnet 80 has the north pole 60 and a south pole 81 while the horseshoe ring magnet has the south pole 62 and a north pole 83. The poles 60, 81 of the inner horseshoe ring magnet 80 are annuli connected at their inner radii by a magnetic cylindrical core annulus 85. Similarly, the poles 62, 83 of the outer horseshoe ring magnet 82 are annuli connected at their outer radii by a magnetic cylindrical core annulus 86. The magnetic circuit consisting of the inner and outer horseshoe ring magnets 80, 82 is a closed circuit because the lines of magnetic flux between the opposing pole pairs 60, 62 and 81, 83 extend straight between the poles and, generally, do not curve outwardly, at least not to the extent of the outwardly curving returning lines of flux 68, 78 of FIGS. 2 and 3.

[0031] In the embodiment of FIGS. 4A, 4B and 6, the opposing magnetic poles 70, 72 across the slit valve opening 50 are each a pole of a respective long horseshoe magnet 90, 92 extending along the length of the slit valve opening 50. the long horseshoe magnet 90 extends along the top boundary of the slit valve opening 50 while the other horseshoe magnet extends along bottom edge of the slit valve opening 50.

[0032] The advantage of the closed magnetic circuit embodiment of FIG. 4 is that the magnetic field confining the plasma does not tend to interfere with plasma processing on the wafer surface.

[0033] In the embodiment of FIGS. 7 and 8, the lower annuli 81, 83 of the two horseshoe ring magnets 80, 82 are joined together as a single annulus by a magnetic core annulus 96, so that the horseshoe ring magnets 80, 82 constitute a single horseshoe ring magnet 94 having a north pole 60 and a south pole 62. The core annulus 96 extends across the pumping annulus 44 and can be protected by a protective coating 98 such as silicon nitride. In order to allow gas to pass through the pumping annulus 44, the core annulus 96 has plural holes 100 extending therethrough.

[0034] One advantage of the invention is that plasma ions are excluded from the pumping annulus 44. This is advantageous because the pumping annulus interior surfaces can be formed of any convenient material without regard to its susceptibility to attack by plasma ions or compatibility of its sputter by-products with the plasma process carried out on the wafer. This also eliminates reduction in plasma density due to loss of plasma ions through the pumping annulus. Another advantage is that gas flow through the pedestal-to-side wall gap 46 is not obstructed even though plasma is confined to the interior chamber 10 over the wafer. Furthermore, by so confining the plasma to a smaller volume (i.e., in the portion of the chamber 10 directly overlying the wafer 52), the plasma density over the wafer 52 is enhanced. A further advantage is that stopping plasma ions from ex-

iting through the slit valve opening 50 eliminates loss of plasma density over portions of the wafer 52 adjacent the slit valve opening 50.

[0035] In one example, each of the magnetic pole pair 60, 62 has a strength of 20 x 10^{-4} Tesla (20 Gauss) for a distance across the gap 46 of 5 cm, while each of the magnetic pole pair 70, 72 has a strength of 20 x 10^{-4} Tesla (20 Gauss) for a width of the slit valve opening 50 of 2 cm.

[0036] While the invention has been described with reference to preferred embodiments in which the plasma confining magnets are protected from attack from plasma ions and processing gases by being at least partially encapsulated in the chamber walls or within the wafer pedestal or within a protective layer, in some embodiments (as for example, the embodiment of FIG. 6) the magnets may be protected by being located entirely outside of the chamber walls. Alternatively, if the reactor designer is willing to permit some plasma interaction with the magnets, magnets may be located inside the chamber in direct contact with the plasma, although this would not be preferred.

[0037] It will be appreciated that many modifications may be made to the above described embodiments without departing from the scope of the invention as determined in the claims.

Claims

1. An RF plasma reactor for processing a semiconductor wafer (20), comprising:

   a reactor chamber (10) bounded by a chamber wall (12), and a gas inlet (22);
   an RF power source (30, 34, 35) and an RF power coupler (26, 32, 36) proximal said chamber (10) and connected to said RF power source (30, 34, 35);
   a wafer pedestal (18) in said chamber (10) for supporting a semiconductor wafer (20) to be processed in said reactor, said wafer pedestal (18) dividing said chamber (10) into an upper processing portion and a lower portion separated by an annular gap (46) between said wafer pedestal (18) and said chamber wall (12) for gas flow between said upper and lower portions of said chamber (10);
   and annular magnetic means (80, 82; 94) extending around the gap to prevent flow of plasma ions through the gap to the lower portion of the chamber; said magnetic means having annular magnetic poles (60, 62) of opposite magnetic polarity placed in face to face relation on opposing sides of said gap (46) and having sufficient magnetic strength to confine plasma ions in said upper processing portion;

   characterised in that the annular magnetic means are of horseshoe form providing said pair of annular poles of opposite polarity in face to face relation across said gap and extending below the gap to provide a closed magnetic circuit without lines of flux extending into the chamber.

2. A reactor as claimed in claim 1, **characterised in that** the annular magnetic means comprise a pair of horseshoe shaped annular magnets (80,82) providing two pairs of oppositely facing annular poles of opposing polarities, one of said pairs being disposed across the gap and the other pair of poles being disposed below the gap, the lines of magnetic flux extending straight between said pairs of poles to complete the magnetic circuit provided by said magnetic means.

3. A reactor as claimed in claim 2, **characterised in that** the other of said pair of annular poles is located below the lower portion of the chamber.

4. A reactor as claimed in claim 3, **characterised in that** a first one of said pairs of magnets (80) comprises:

   an inner cylindrical core (85) concentric with said wafer pedestal and having an inner top end and an inner bottom end,
   and a pair of inner annuli extending radially outwardly from said inner top end and said inner bottom end respectively, the poles (60, 81) of said first magnet being comprised in said pair of inner annuli respectively;
   and **in that** the other one of said pair of magnets (82) comprises:

      an outer cylindrical core (86) concentric with and surrounding said inner cylindrical core and having an outer top and an outer bottom end,
      and a pair of outer annuli extending radially inwardly from said outer top end and said outer bottom end respectively, the poles (62, 83) of said other magnet being comprised within said pair of outer annuli respectively.

5. A reactor as claimed in claim 1, **characterised in that** the annular magnetic means comprises a single horseshoe shaped ring magnet (94) having an annular core and said pair of annular poles (60, 62) of opposite polarities are located in face to face on opposite sides of the annular gap and said core (96) extends through said lower portion of said chamber (10).

6. A reactor as claimed in claim 5, **characterised in**

that gas passages (100) extend through said core (96) for permitting gas flow through said lower portion of said chamber (10).

7. A reactor as claimed in claim 6, further comprising a protective coating around said core (96) portion.

8. A reactor as claimed in claim 7, **characterised in that** the annular core comprises an inner cylindrical core and a concentric outer cylindrical core, the upper ends of the inner and outer cores having respectively outward and inwardly facing annular poles of opposing polarities facing across the gap and the lower ends of the inner and outer cores being connected by a radially extending core extending through the lower portion of the chamber.

9. A reactor as claimed in claim 1, further comprising a slit valve opening (50) forming a gap in said chamber wall (12) having opposing sides and a pair of valve magnets (74, 76) disposed side-by-side whereby each pole (70, 72) of each valve magnet faces an opposite pole of the other valve magnet, each of said valve magnets (74, 76) having poles (70, 72) of opposite polarity located along respective opposing sides of said slit valve (50).

10. A reactor as claimed in claim 9, **characterised in that** said first pair of facing poles (70, 72) of the two valve magnets (74, 76) face each other across said slit valve opening (50) while the second pair of facing poles of said two valve magnets (74, 76) face each other at a location radially outwardly displaced of the chamber wall from said slit valve opening (50).

11. A reactor as claimed in claim 9, **characterised in that** said pairs of facing poles (70, 72) are separated by gaps sufficient to permit a passage of a semiconductor wafer (20) therebetween.

12. A reactor as claimed in claim 9, **characterised in that** said valve magnets (74, 76) are horseshoe magnets.

13. A reactor as claimed in claim 1, **characterised in that** the lower portion of the chamber comprises a pumping annulus (44) formed adjacent a peripheral portion (56) of said chamber and a vacuum pump (40) being coupled to said pumping annulus, and said pumping annulus being coupled to said chamber through said gap (46) between said pedestal and said chamber wall.

14. An RF plasma reactor for processing a semiconductor wafer (20), comprising:

a reactor chamber (10) bounded by a chamber wall (12), and a gas inlet (22);
an RF power source (30, 34, 35) and an RF power coupler (26, 32, 26) proximal said chamber and connected to said RF power source (30, 34, 35);
a wafer pedestal (18) in said chamber (10) for supporting a semiconductor wafer (20) to be processed in said reactor;
and a slit valve opening (50) through said chamber wall (12) affording ingress and egress of a wafer (20) to and from said chamber, said slit valve opening (50) having opposing sides defining said opening;

characterised in that a pair of valve magnets (90, 92) is provided, each having a pole located along a respective opposing sides of said slit valve opening,

a first pair of poles (70, 72) of the respective valve magnets of opposite polarity being located along opposite sides of said slit valve opening facing each other and adjacent the opening while a second pair of poles of the respective valve magnets (74, 76) of opposite polarity facing each other at a location outwardly displaced away from said slit value opening, said pair of valve magnets thereby constituting a closed magnet circuit.

15. A reactor as claimed in claim 14, **characterised in that** said facing poles are separated by gaps sufficient to permit passage of a semiconductor wafer (20) therebetween.

16. A reactor as claimed in claim 14, **characterised in that** said valve magnets (90, 92) are horseshoe magnets.

17. A reactor as claimed in claim 16, **characterised in that** said second pair of magnetic poles are of opposite magnetic polarity placed adjacent each other, wherein a first pole (70, 72) of the first pair of magnetic poles is connected to a first pole of the second pair of magnetic poles having a polarity opposite from the first pole of the first pair of magnetic poles (70, 72) by a first link comprised of a magnetic material, and **in that** a second pole of the first pair of magnetic poles is connected to a second pole of the second pair of magnetic poles having a polarity opposite from the second pole of the first pair of magnetic poles by a second link comprised of magnetic material.

Patentansprüche

1. HF-Plasmareaktor für die Behandlung eines Halbleiterwafers (20)

- mit einer von einer Kammerwand (12) umschlossenen Reaktorkammer (10) und mit einem Gaseinlass (22),
- mit einer HF-Leistungsquelle (30, 34, 35) und einer HF-Leistungseinkoppelungseinrichtung (26, 32, 36), die sich nahe bei der Kammer (10) befindet und an die HF-Leistungsquelle (30, 34, 35) angeschlossen ist,
- mit einem Wafersockel (18) in der Kammer (10) zum Halten eines in dem Reaktor zu behandelnden Halbleiterwafers (20), wobei der Wafersockel (18) die Kammer (10) in einen oberen Behandlungsteil und einen unteren Teil unterteilt, die durch einen Ringspalt (46) zwischen dem Wafersockel (18) und der Kammerwand (12) für einen Gasstrom zwischen dem oberen und unteren Teil der Kammer (10) getrennt sind, und
- mit ringförmigen Magneteinrichtungen (80, 82; 94), die sich um den Spalt erstrecken, um einen Strom von Plasmaionen durch den Spalt zu dem unteren Teil der Kammer zu verhindern, wobei die Magneteinrichtungen ringförmige Magnetpole (60, 62) mit entgegengesetzter magnetischer Polarität haben, die ein in einer einander zugewandten Beziehung auf gegenüberliegenden Seiten des Spaltes (46) angeordnet sind und eine ausreichende Magnetstärke haben, um Plasmaionen in dem oberen Behandlungsteil einzuschließen,

dadurch gekennzeichnet,

- **dass** die ringförmigen Magneteinrichtungen eine Hufeisenform haben, das Paar von ringförmigen Polen mit entgegengesetzter Polarität in einer einander zugewandten Beziehung über dem Spalt bilden und sich unter den Spalt erstrecken, um einen geschlossenen magnetischen Kreis zu bilden, ohne dass sich Magnetflusslinien in die Kammer erstrekken.

2. Reaktor nach Anspruch 1, **dadurch gekennzeichnet, dass** die ringförmigen Magneteinrichtungen ein Paar von hufeisenförmigen ringförmigen Magneten (80, 82) aufweisen, die zwei Paare von gegenüberliegend zugewandten Ringpolen mit entgegengesetzten Polaritäten haben, wobei eines der Paare quer über dem Spalt und das andere Paar von Polen unter dem Spalt angeordnet ist und sich die magnetischen Flusslinien gerade zwischen den Paaren von Polen erstrecken, um den Magnetkreis zu vervollständigen, der von den Magneteinrichtungen gebildet wird.

3. Reaktor nach Anspruch 2, **dadurch gekennzeichnet, dass** sich das andere Paar der ringförmigen Pole unter dem unteren Teil der Kammer befindet.

4. Reaktor nach Anspruch 3, **dadurch gekennzeichnet,**

- **dass** das erste Paar von Magneten (80) einen inneren zylindrischen Kern (85), der zum Wafersockel konzentrisch ist und ein inneres oberes Ende und ein inneres unteres Ende hat, und ein Paar von inneren Ringen aufweist, die sich von dem inneren oberen Ende beziehungsweise dem inneren unteren Ende radial nach außen erstrecken, wobei die Pole (60, 81) des ersten Magneten jeweils in dem Paar von inneren Ringen enthalten sind,
- und **dass** das andere Paar von Magneten (82) einen äußeren zylindrischen Kern (86), der konzentrisch zu dem inneren zylindrischen Kern ist, diesen umgibt und ein äußeres oberes und ein äußeres unteres Ende hat, und ein Paar von äußeren Ringen aufweist, die sich von dem äußeren oberen Ende beziehungsweise dem äußeren unteren Ende radial nach innen erstrekken, wobei die Pole (62, 83) des anderen Magneten jeweils in dem Paar von äußeren Ringen enthalten sind.

5. Reaktor nach Anspruch 1, **dadurch gekennzeichnet, dass** die ringförmigen Magneteinrichtungen einen einzigen hufeisenförmigen Ringmagneten (94) aufweisen, der einen ringförmigen Kern hat, dass das Paar von ringförmigen Polen (60, 62) mit entgegengesetzten Polaritäten einander zugewandt auf gegenüberliegende Seiten des ringförmigen Spalts angeordnet sind, und sich der Kern (96) durch den unteren Teil der Kammer (10) erstreckt.

6. Reaktor nach Anspruch 5, **dadurch gekennzeichnet, dass** sich durch den Kern (96) Gaskanäle (100) erstrecken, die einen Gasstrom durch den unteren Teil der Kammer (10) erlauben.

7. Reaktor nach Anspruch 6, welcher weiterhin eine Schutzbeschichtung um den Kernteil (96) herum aufweist.

8. Reaktor nach Anspruch 7, **dadurch gekennzeichnet, dass** der ringförmige Kern einen inneren zylindrischen Kern und einen konzentrischen äußeren zylindrischen Kern aufweist, wobei die oberen Enden des inneren und äußeren Kerns jeweils nach außen und nach innen weisende ringförmige Pole mit entgegengesetzten Polaritäten haben, die quer über den Spalt weisen, wobei die unteren Enden des inneren und äußeren Kerns durch einen radial verlaufenden Kern verbunden sind, der sich durch den unteren Teil der Kammer erstreckt.

9. Reaktor nach Anspruch 1, welcher weiterhin eine Schlitzventilöffnung (50) aufweist, die einen Spalt

in der Kammerwand (12) bildet, welcher gegenüberliegende Seiten und ein Paar von Ventilmagneten (74, 76) hat, die Seite an Seite angeordnet sind, wodurch jeder Pol (70, 72) eines jeden Ventilmagneten dem entgegengesetzten Pol des anderen Ventilmagneten zugewandt ist, wobei jeder der Ventilmagneten (74, 76) Pole (70, 72) mit entgegengesetzter Polarität hat, die jeweils längs der gegenüberliegenden Seiten des Schlitzventils (50) angeordnet sind.

10. Reaktor nach Anspruch 9, **dadurch gekennzeichnet, dass** das erste Paar von gegenüberstehenden Polen (70, 72) der beiden Ventilmagnete (74, 76) quer über die Schlitzventilöffnung (50) einander zugewandt sind, während das zweite Paar von gegenüberstehenden Polen der beiden Ventilmagnete (74, 76) einander an einer Stelle zugewandt sind, die von der Kammerwand von der Schlitzventilöffnung (50) aus radial nach außen verschoben ist.

11. Reaktor nach Anspruch 9, **dadurch gekennzeichnet, dass** die Paare von gegenüberstehenden Polen (70, 72) durch Spalte getrennt sind, die ausreichen, um einen Durchgang eines Halbleiterwafers (20) dazwischen zu ermöglichen.

12. Reaktor nach Anspruch 9, **dadurch gekennzeichnet, dass** die Ventilmagnete (72, 76) Hufeisenmagnete sind.

13. Reaktor nach Anspruch 1, **dadurch gekennzeichnet, dass** der untere Teil der Kammer einen Pumpring (44), der angrenzend an einen Umfangsteil (56) der Kammer ausgebildet ist, und eine Vakuumpumpe (40) aufweist, die mit dem Pumpring verbunden ist, wobei der Pumpring mit der Kammer durch den Spalt (46) zwischen dem Sockel und der Kammerwand gekoppelt ist.

14. HF-Plasmareaktor zur Behandlung eines Halbleiterwafers (20)

- mit einer von einer Kammerwand (12) umgebenen Reaktorkammer (10), die einen Gaseinlass (22) hat,
- mit einer HF-Leistungsquelle (30, 34, 35) und einer HF-Leistungseinkoppelungseinrichtung (26, 32, 36), die nahe an der Kammer angeordnet und mit der Hf-Leistungsquelle (30, 34, 35) verbunden ist,
- mit einem Wafersockel (18) in der Kammer (10) zum Tragen eines in dem Reaktor zu behandelnden Halbleiterwafers (20) und
- mit einer Schlitzventilöffnung (50) durch die Kammerwand (12), die einen Eintritt und einen Austritt eines Wafers (20) in die Kammer und aus ihr heraus ermöglicht, wobei die Schlitzventilöffnung (50) gegenüberliegende Seiten hat, die die Öffnung bilden,

dadurch gekennzeichnet,

- **dass** ein Paar von Ventilmagneten (90, 92) vorgesehen ist, von denen jeder einen Pol hat, der sich auf einer entsprechenden gegenüberliegenden Seite der Schlitzventilöffnung befindet, und
- **dass** ein erstes Paar von Polen (70, 72) der jeweiligen Ventilmagnete mit entgegengesetzter Polarität längs gegenüberliegender Seiten der Schlitzventilöffnung einander zugewandt und angrenzend an die Öffnung angeordnet sind, während ein zweites Paar von Polen der jeweiligen Ventilmagnete (74, 76) mit entgegengesetzter Polarität einander an einer Stelle zugewandt sind, die nach außen weg von der Schlitzventilöffnung verschoben ist, wobei das Paar von Ventilmagneten dadurch einen geschlossenen Magnetkreis bildet.

15. Reaktor nach Anspruch 14, **dadurch gekennzeichnet, dass** die gegenüberstehenden Pole durch Spalte getrennt sind, die ausreichen, um den Durchgang eines Halbleiterwafers (20) dazwischen zu ermöglichen.

16. Reaktor nach Anspruch 14, **dadurch gekennzeichnet, dass** die Ventilmagnete (90, 92) Hufeisenmagnete sind.

17. Reaktor nach Anspruch 16, **dadurch gekennzeichnet, dass** das zweite Paar von Magnetpolen eine entgegengesetzte magnetische Polarität haben und zueinander benachbart angeordnet sind, wobei einer erster Pol (70, 72) des ersten Paars von Magnetpolen mit einem ersten Pol des zweiten Paars von Magnetpolen, die eine zu dem ersten Pol des ersten Paars von Magnetpolen (70, 72) entgegengesetzte Polarität hat, durch ein erstes Glied verbunden ist, das ein magnetisches Material aufweist, und dass ein zweiter Pol des ersten Paars von Magnetpolen mit einem zweiten Pol des zweiten Paars von Magnetpolen, die eine zu dem zweiten Pol des ersten Paars von Magnetpolen entgegengesetzte Polarität hat, durch ein zweites Glied verbunden ist, das ein magnetisches Material aufweist.

Revendications

1. Réacteur à plasma RF pour le traitement d'une tranche semiconductrice (20), comportant :

une chambre (10) de réacteur délimitée par une

paroi (12) de chambre, et une entrée (22) de gaz ;
une source d'énergie RF (30, 34, 35) et un coupleur d'énergie RF (26, 32, 36) proche de ladite chambre (10) et connecté à ladite source d'énergie RF (30, 34, 35) ;
un socle (18) pour tranche dans ladite chambre (10) destiné à supporter une tranche semiconductrice (20) devant être traitée dans ledit réacteur, ledit socle (18) pour tranche divisant ladite chambre (10) en une partie supérieure de traitement et une partie inférieure séparées par un intervalle annulaire (46) entre ledit socle (18) pour tranche et ladite paroi (12) de la chambre pour un écoulement de gaz entre lesdites parties supérieure et inférieure de ladite chambre (10) ;
et des moyens magnétiques annulaires (80, 82 ; 94) s'étendant autour de l'intervalle afin d'empêcher un flux d'ions de plasma à travers l'intervalle vers la partie inférieure de la chambre ; lesdits moyens magnétiques comportant des pôles magnétiques annulaires (60, 62) de polarités magnétiques opposées placés face à face sur des côtés opposés dudit intervalle (46) et ayant une force magnétique suffisante pour confiner les ions du plasma dans ladite partie supérieure de traitement ;

caractérisé en ce que les moyens magnétiques annulaires sont en forme de fer à cheval fournissant ladite paire de pôles annulaires de polarités opposées dans une disposition face à face à travers ledit intervalle et s'étendant en dessous de l'intervalle pour former un circuit magnétique fermé sans ligne de flux pénétrant dans la chambre.

2. Réacteur selon la revendication 1, **caractérisé en ce que** les moyens magnétiques annulaires comprennent une paire d'aimants annulaires (80, 82) en forme de fer à cheval fournissant deux paires de pôles annulaires opposés, de polarités opposées, l'une desdites paires étant disposée à travers l'intervalle et l'autre paire de pôles étant disposée en dessous de l'intervalle, les lignes de flux magnétique s'étendant directement entre lesdites paires de pôles pour fermer le circuit magnétique produit par lesdits moyens magnétiques.

3. Réacteur selon la revendication 2, **caractérisé en ce que** l'autre desdites paires de pôles magnétiques est placé en dessous de la partie inférieure de la chambre.

4. Réacteur selon la revendication 3, **caractérisé en ce qu**'une première desdites paires d'aimants (80) comporte :

un noyau cylindrique intérieur (85) concentrique avec ledit socle pour tranche et ayant une extrémité supérieure intérieure et une extrémité inférieure intérieure,
et une paire d'anneaux intérieurs s'étendant radialement vers l'extérieur depuis ladite extrémité supérieure intérieure et ladite extrémité inférieure intérieure, respectivement, les pôles (60, 81) dudit premier aimant étant compris dans ladite paire d'anneaux intérieurs, respectivement ;
et **en ce que** l'autre de ladite paire d'aimants (82) comporte :

un noyau cylindrique extérieur (86) concentrique audit noyau cylindrique intérieur qu'il entoure et ayant des extrémités supérieure extérieure et inférieure extérieure,
et une paire d'anneaux extérieurs s'étendant radialement vers l'intérieur depuis ladite extrémité supérieure extérieure et ladite extrémité inférieure extérieure, respectivement, les pôles (62, 83) dudit autre aimant étant compris dans ladite paire d'anneaux extérieurs, respectivement.

5. Réacteur selon la revendication 1, **caractérisé en ce que** les moyens magnétiques annulaires comprennent un aimant annulaire unique (94) en forme de fer à cheval ayant un noyau annulaire et ladite paire de pôles annulaires (60, 62) de polarités opposées sont placés face à face sur des côtés opposés de l'intervalle annulaire et ledit noyau (96) s'étend à travers ladite partie inférieure de ladite chambre (10).

6. Réacteur selon la revendication 5, **caractérisé en ce que** des passages (100) de gaz s'étendent à travers ledit noyau (96) pour permettre un écoulement de gaz à travers ladite partie inférieure de ladite chambre (10).

7. Réacteur selon la revendication 6, comportant en outre un revêtement protecteur autour de ladite partie de noyau (96).

8. Réacteur selon la revendication 7, **caractérisé en ce que** le noyau annulaire comporte un noyau cylindrique intérieur et un noyau cylindrique extérieur concentrique, les extrémités supérieures des noyaux intérieur et extérieur ayant des pôles annulaires tournés respectivement vers l'extérieur et vers l'intérieur, de polarités opposées, se faisant face à travers l'intervalle, et les extrémités inférieures des noyaux intérieur et extérieur étant reliées par un noyau disposé radialement, qui s'étend à travers la partie inférieure de la chambre.

9. Réacteur selon la revendication 1, comportant en outre une ouverture (50) de valve à fente formant un intervalle dans ladite paroi (12) de la chambre ayant des côtés opposés et une paire d'aimants de valve (74, 76) disposés côte à côte, grâce à quoi chaque pôle (70, 72) de chaque aimant de valve fait face à un pôle opposé de l'autre aimant de valve, chacun desdits aimants de valve (74, 76) ayant des pôles (70, 72) de polarités opposées placés le long de côtés opposés respectifs de ladite valve à fente (50).

10. Réacteur selon la revendication 9, **caractérisé en ce que** ladite première paire de pôles face à face (70, 72) des deux aimants de valve (74, 76) se font face à travers ladite ouverture (50) de valve à fente, tandis que la seconde paire de pôles face à face desdits deux aimants de valve (74, 76) se font face en un emplacement décalé radialement vers l'extérieur de la paroi de la chambre à partir de ladite ouverture (50) de valve à fente.

11. Réacteur selon la revendication 9, **caractérisé en ce que** lesdites paires de pôles face à face (70, 72) sont séparées par des intervalles suffisants pour permettre le passage d'une tranche semiconductrice (20) entre eux.

12. Réacteur selon la revendication 9, **caractérisé en ce que** lesdits aimants de valve (74, 76) sont des aimants en fer à cheval.

13. Réacteur selon la revendication 1, **caractérisé en ce que** la partie inférieure de la chambre comporte un espace annulaire (44) de pompage formé de façon à être adjacent à une partie périphérique (56) de ladite chambre et une pompe à vide (40) raccordée audit espace annulaire de pompage, et ledit espace annulaire de pompage étant raccordé à ladite chambre à travers ledit intervalle (46) entre ledit socle et ladite paroi de la chambre.

14. Réacteur à plasma RF pour le traitement d'une tranche semiconductrice (20), comportant :

une chambre (10) de réacteur délimitée par une paroi (12) de chambre, et une entrée (22) de gaz ;
une source d'énergie RF (30, 34, 35) et un coupleur d'énergie RF (26, 32, 26) proche de ladite chambre et connecté à ladite source d'énergie RF (30, 34, 35) ;
un socle (18) pour tranche dans ladite chambre (10) destiné à supporter une tranche semiconductrice (20) devant être traitée dans ledit réacteur ;
et une ouverture (50) de valve à fente traversant ladite paroi (12) de la chambre, permettant à une tranche (20) d'entrer dans ladite chambre et d'en sortir, ladite ouverture (50) de valve à fente ayant des côtés opposés définissant ladite ouverture ; **caractérisé en ce qu**'une paire d'aimants (90, 92) de valve est prévue, ayant chacun un pôle placé le long d'un, respectif, des côtés opposés de ladite ouverture de valve à fente,
une première paire de pôles (70, 72) des aimants de valve respectifs de polarités opposées étant placée le long de côtés opposés de ladite ouverture de valve à fente, face à face et à proximité immédiate de l'ouverture, tandis qu'une seconde paire de pôles des aimants de valve respectifs (74, 76) de polarités opposées se font face en un emplacement décalé vers l'extérieur et à l'écart de ladite ouverture de valve à fente, ladite paire d'aimants de valve constituant ainsi un circuit magnétique fermé.

15. Réacteur selon la revendication 14, **caractérisé en ce que** lesdits pôles face à face sont séparés par des intervalles suffisants pour permettre le passage entre eux d'une tranche semiconductrice (20).

16. Réacteur selon la revendication 14, **caractérisé en ce que** lesdits aimants de valve (90, 92) sont des aimants en fer à cheval.

17. Réacteur selon la revendication 16, **caractérisé en ce que** ladite seconde paire de pôles magnétiques sont de polarités magnétiques opposées, placés de façon à être adjacents l'un à l'autre, un premier pôle (70, 72) de la première paire de pôles magnétiques étant connecté à un premier pôle de la seconde paire de pôles magnétiques ayant une polarité opposée par rapport au premier pôle de la première paire de pôles magnétiques (70, 72) par une première liaison constituée d'une matière magnétique, et **en ce qu**'un second pôle de la première paire de pôles magnétiques est connecté à un second pôle de la seconde paire de pôles magnétiques ayant une polarité opposée à celle du second pôle de la première paire de pôles magnétiques, par une seconde liaison constituée d'une matière magnétique.

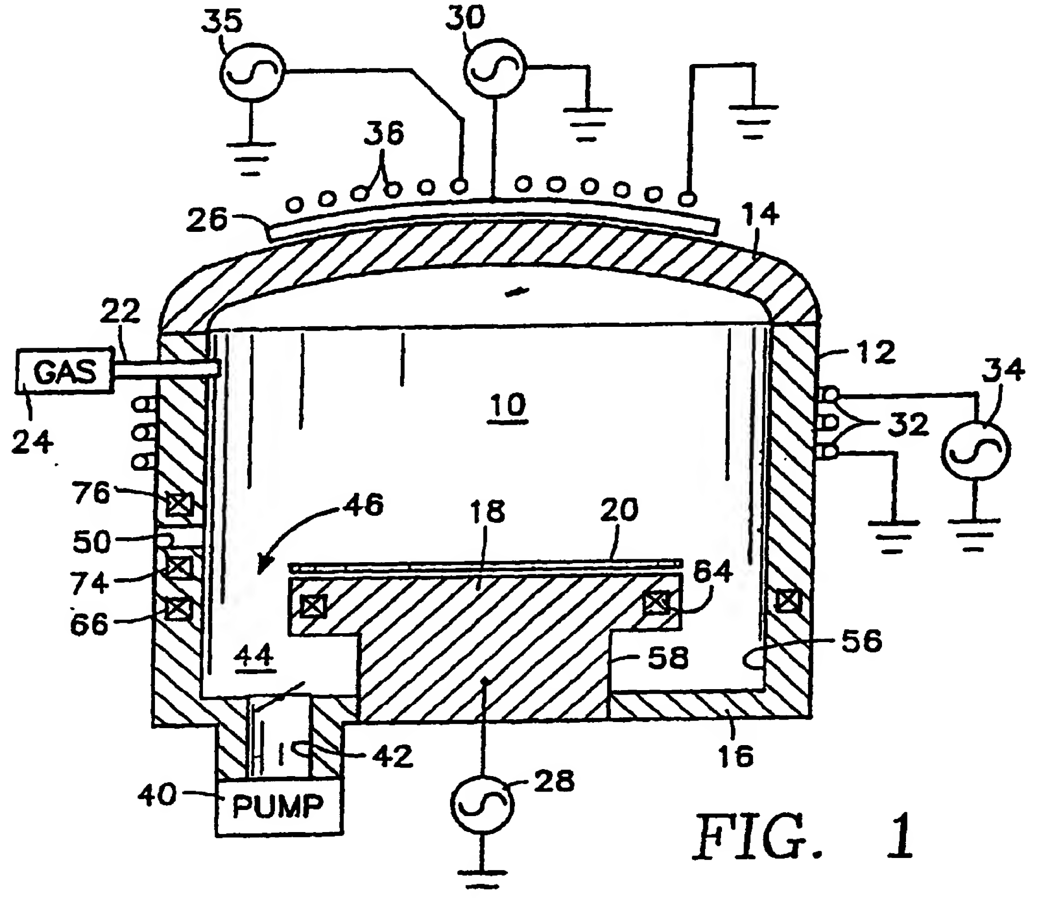


FIG. 1

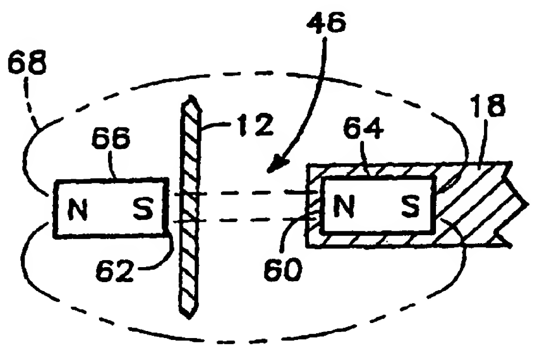


FIG. 2

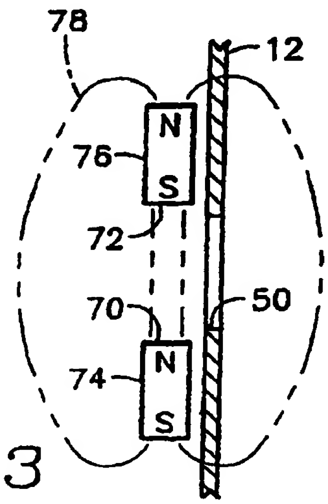
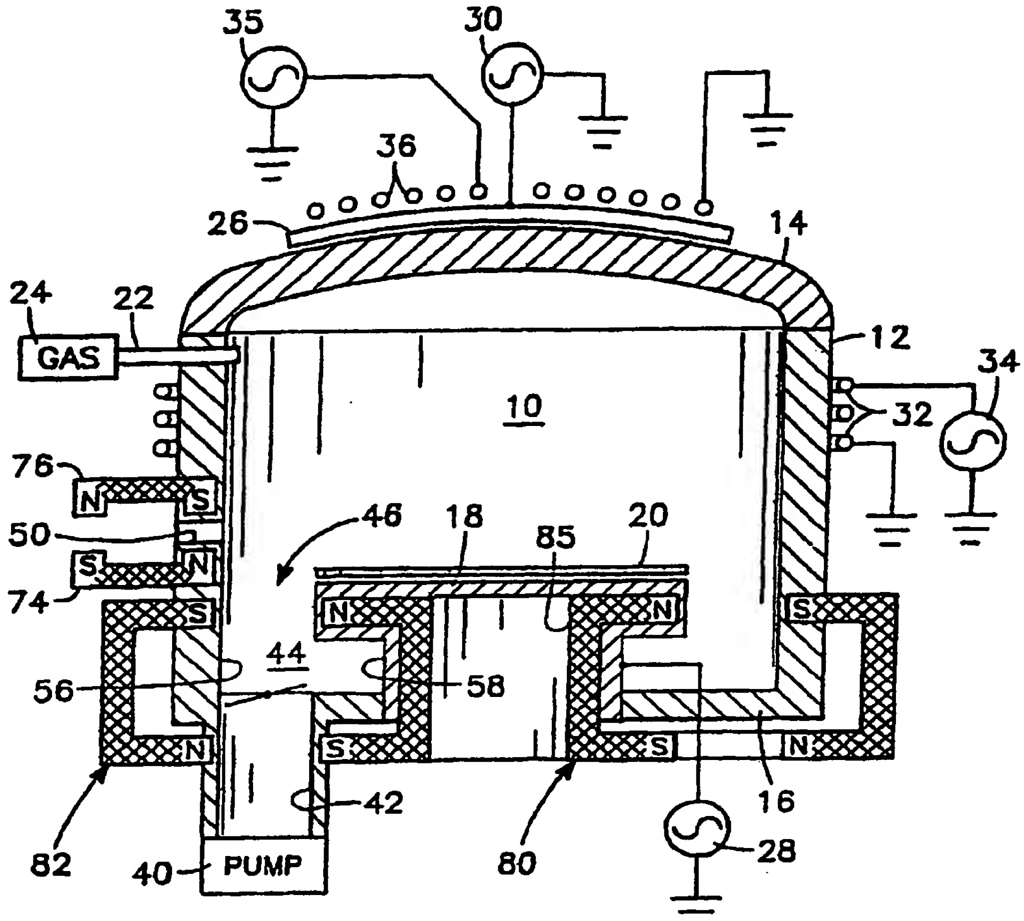


FIG. 3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36
26
14
24
22
GAS
12
34
10
32
76
N
S
50
N
S
74
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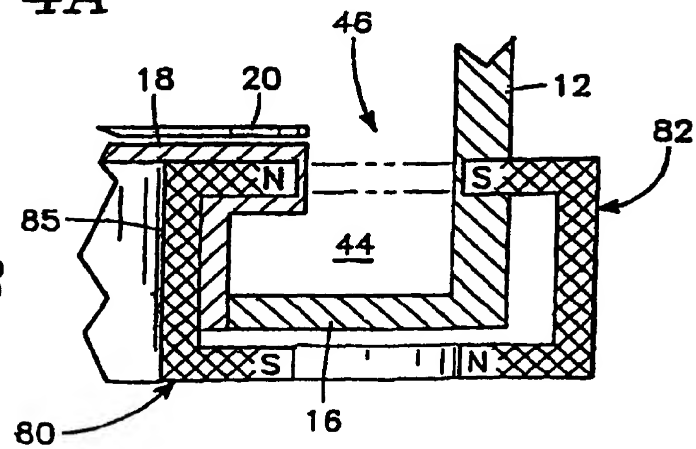
46
18
85
20
N
N
S
44
56
58
S
N
N
S
S
N
42
16
28
82
40
PUMP
80

FIG. 4A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18
20
12
82
N
S
85
44
S
N
16
80

FIG. 4B

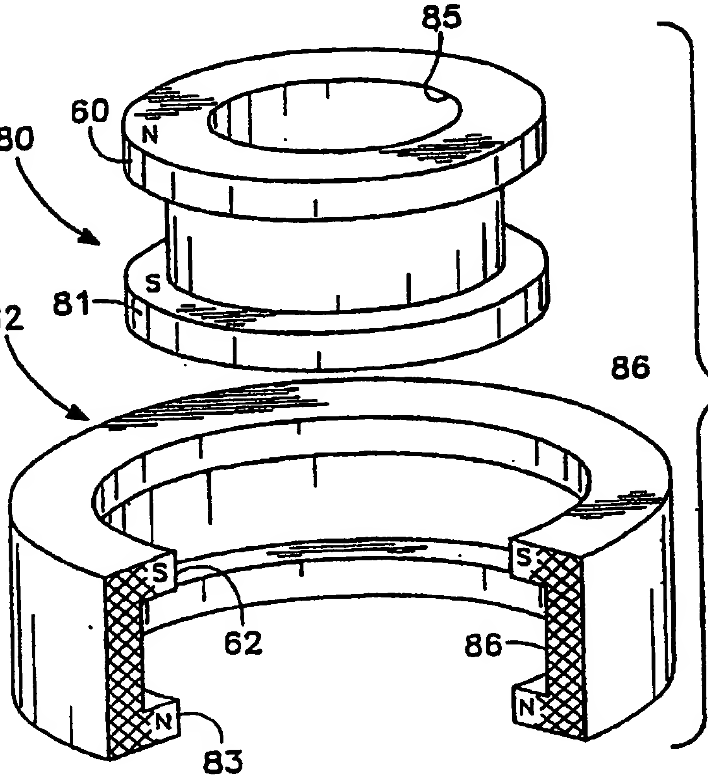


FIG. 5

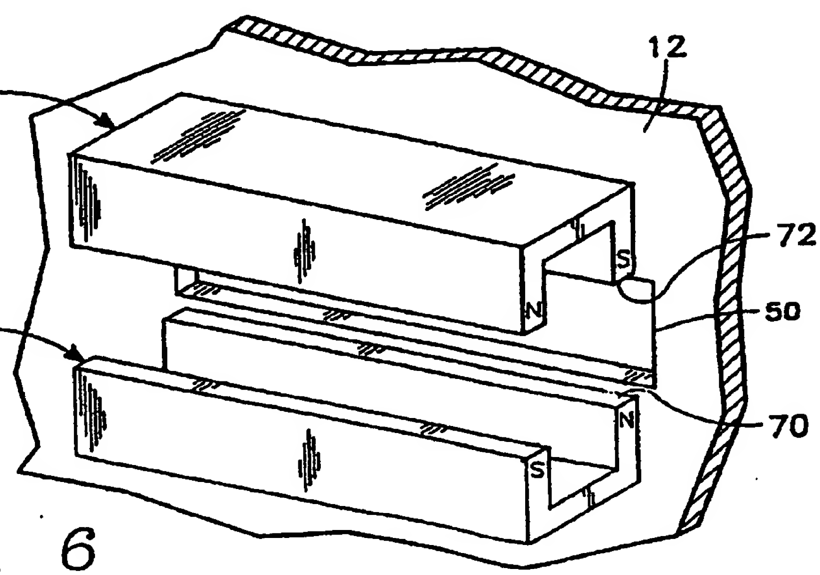
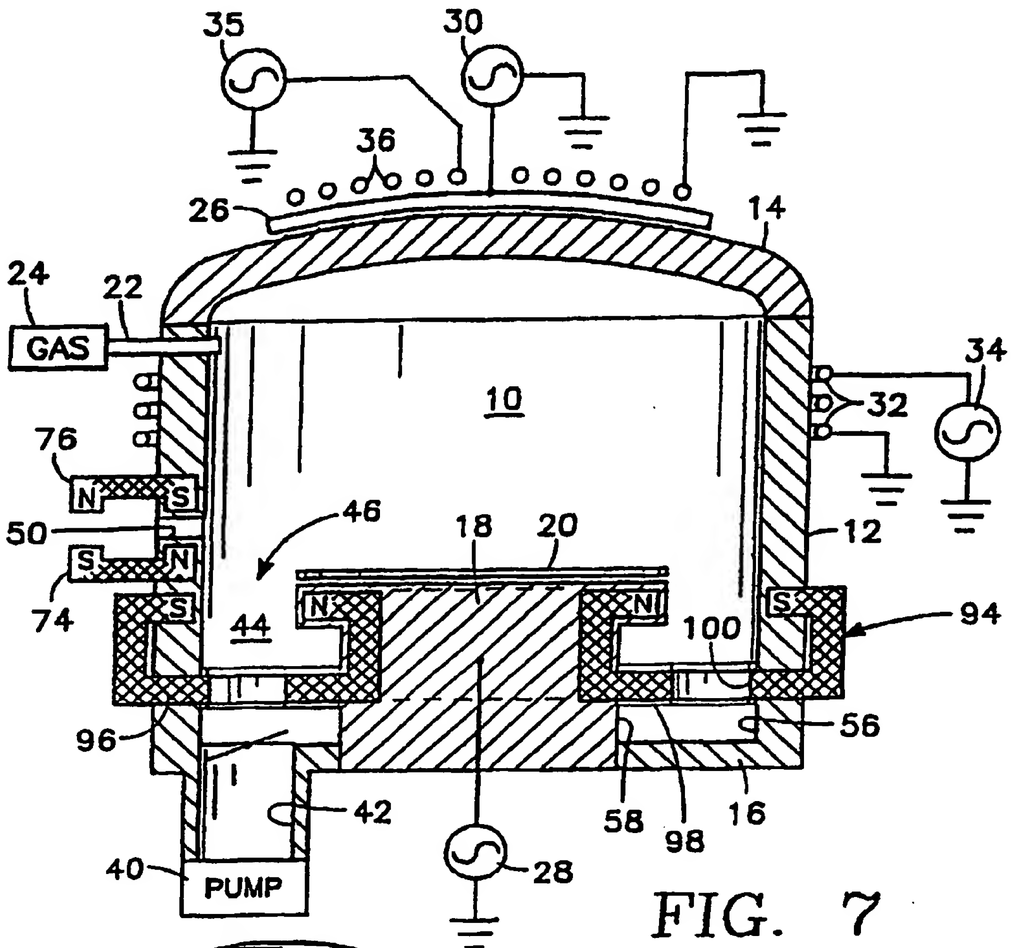


FIG. 6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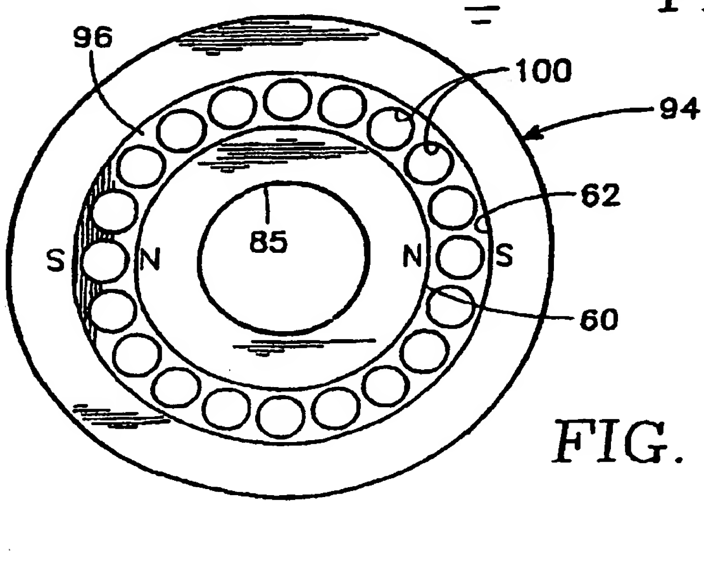
14
24
22
GAS
10
34
32
76
N
S
50
S
N
74
S
46
18
20
12
44
N
N
S
100
94
96
56
42
58
98
16
40
PUMP
28

FIG. 7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100
94
62
S
N
85
N
S
60

FIG. 8